A Scalable and Extensible Earth System Model for Climate Change Science

(aka SciDAC CCSM Consortium)

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Modest Ambitions

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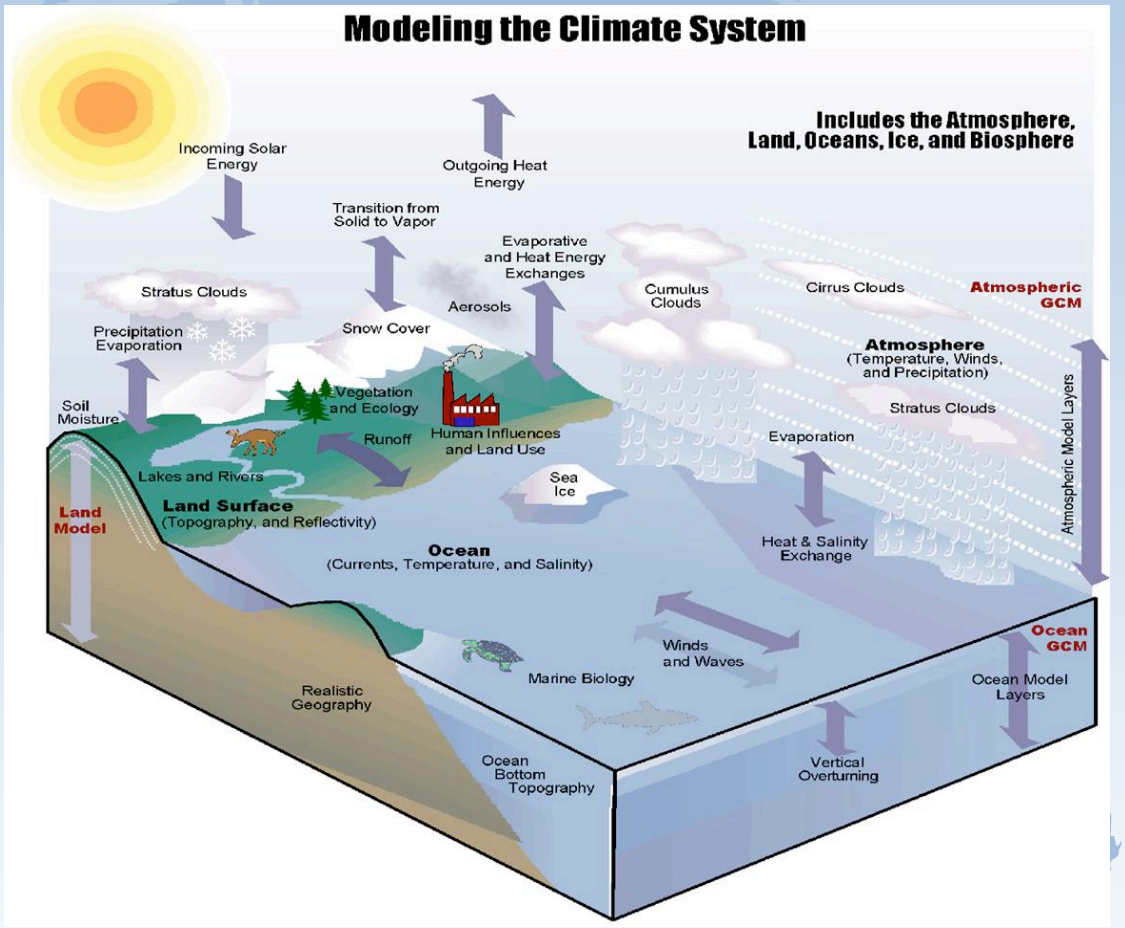
Modest Ambitions

Simulate this →



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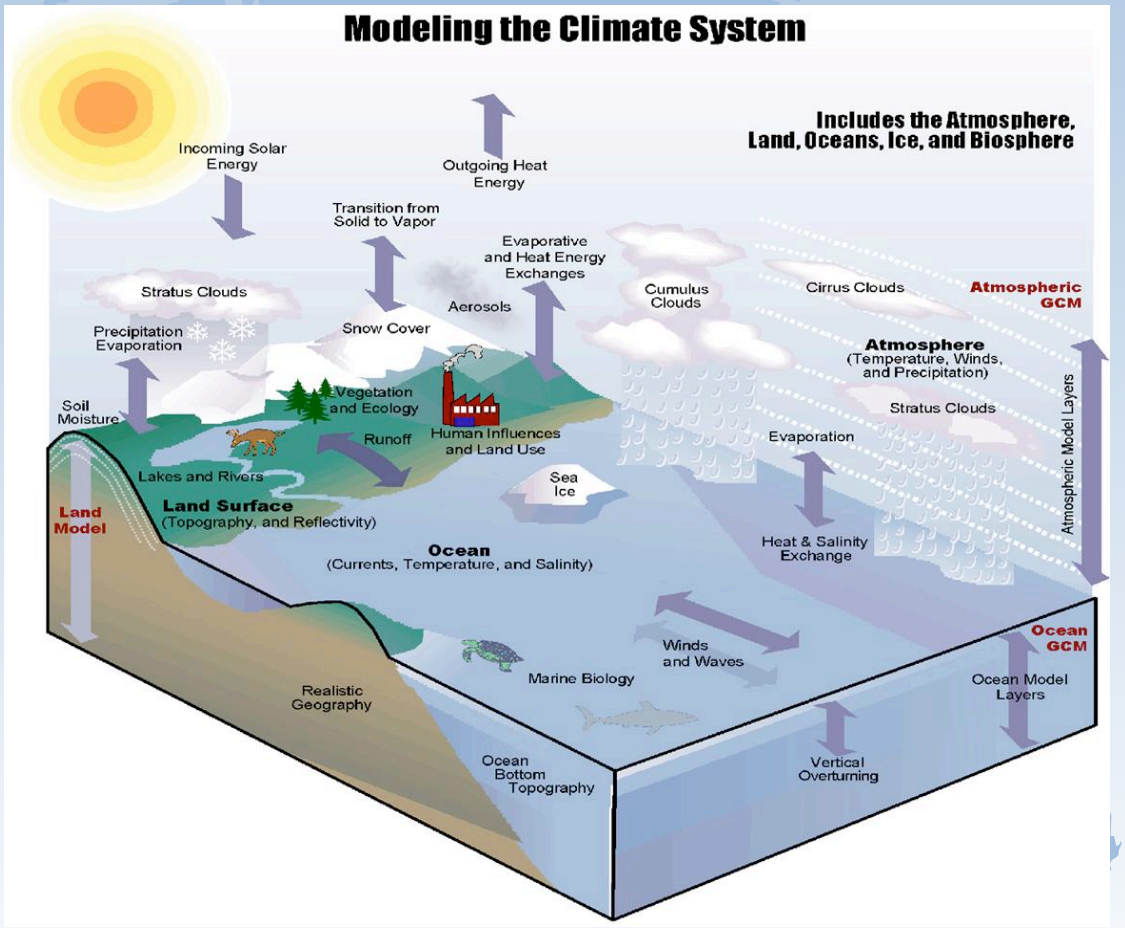
Modest Ambitions

Simulate this

Determine range of possible climate changes using a more accurate climate system model that includes the full range of human and natural climate feedbacks with increased realism and spatial resolution



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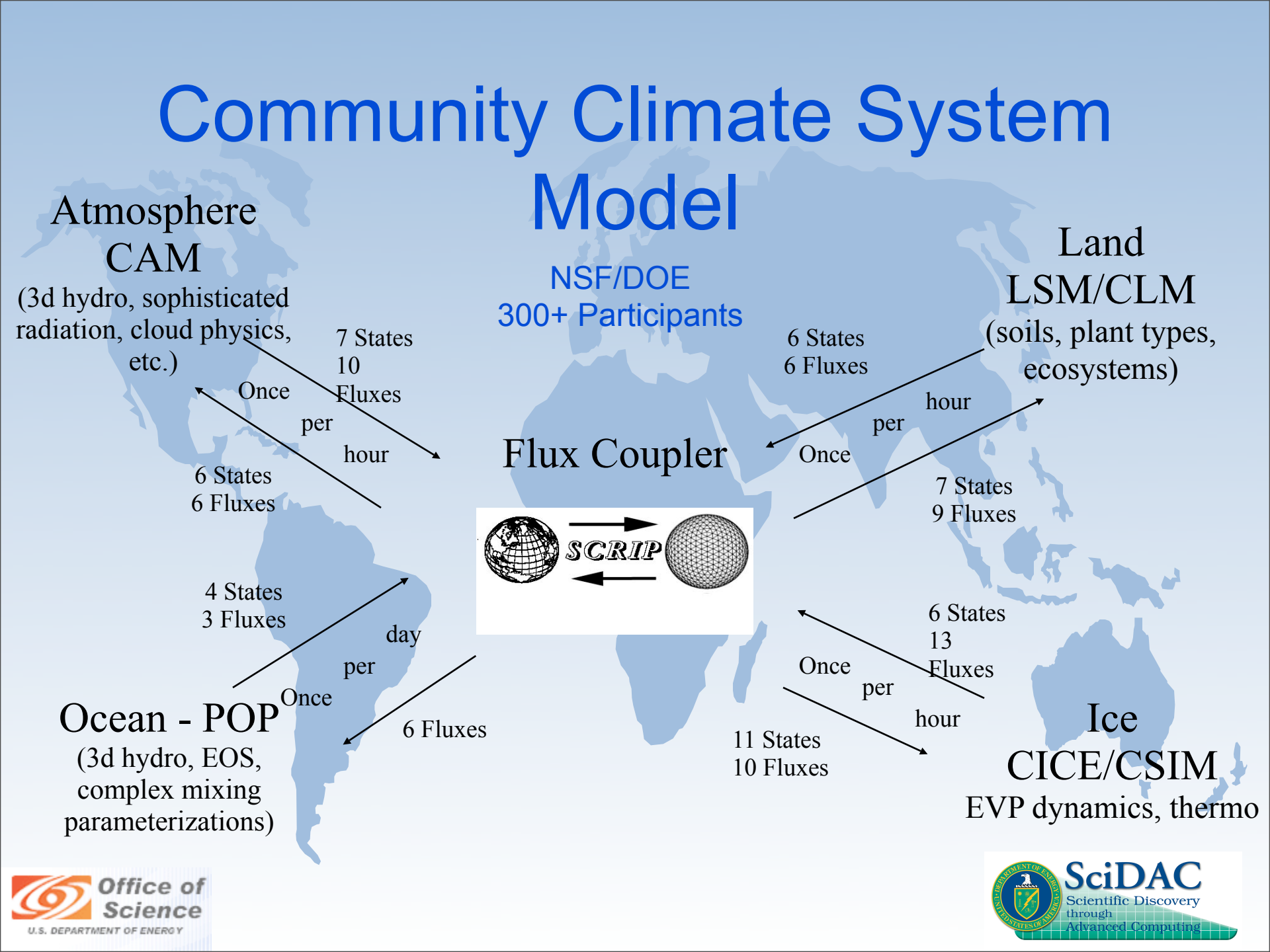
Three Simple Tasks

- Earth System Model
  - Adding all the chemical and biogeochemical feedbacks
- Model Integration and Evaluation
  - Adding other new stuff and *evaluating* how well it improves the model
- Performance/scaling

Community Climate System Model

NSF/DOE
300+ Participants



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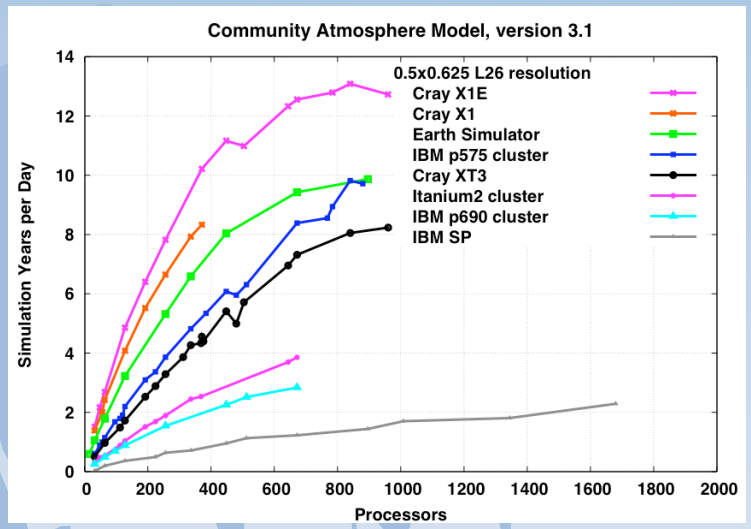
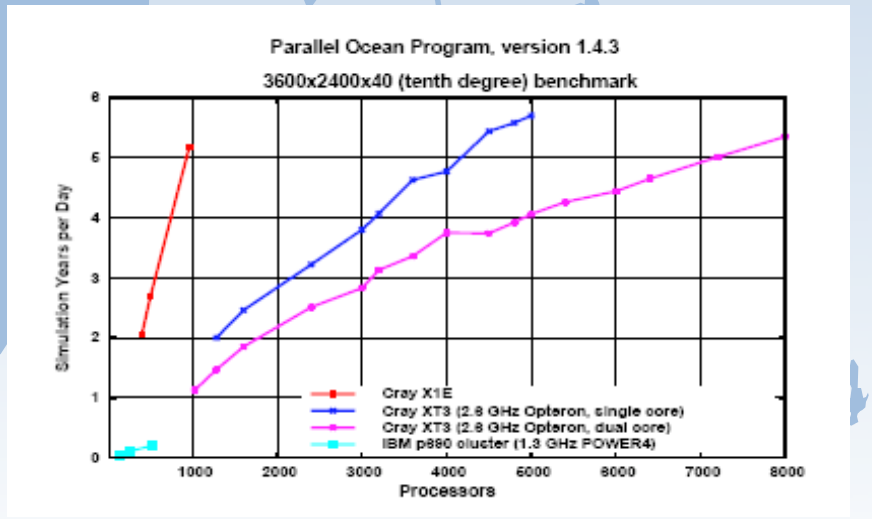
Performance and Scalability

- Performance engineering
- Scalability for petascale science applications
- Coupling strategies
- Limited viz role
  - Load imbalance
  - bottlenecks





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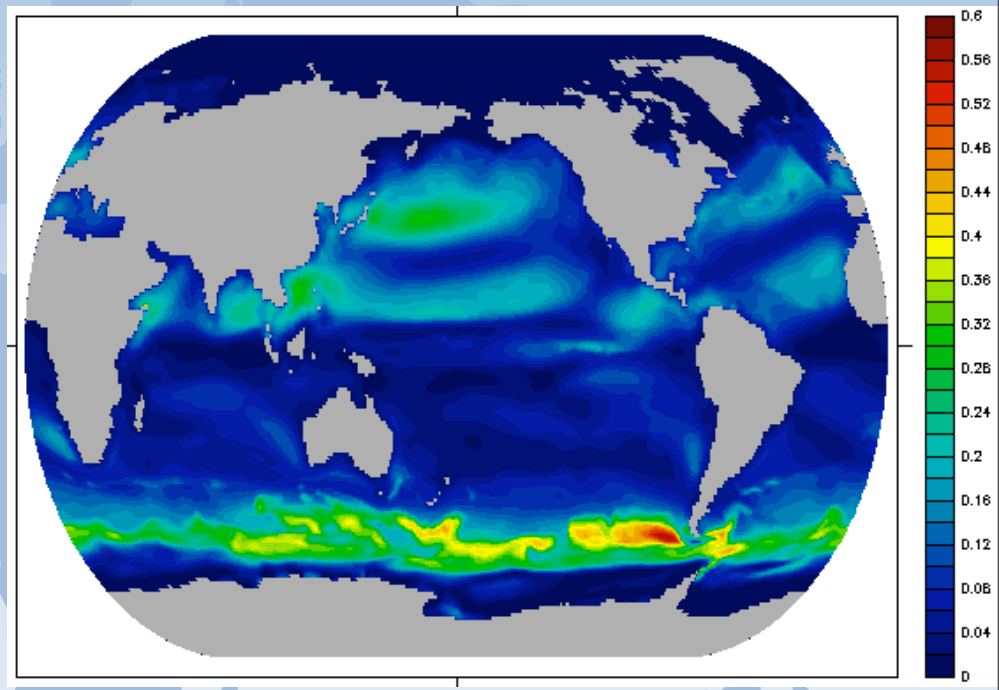
Earth System Model

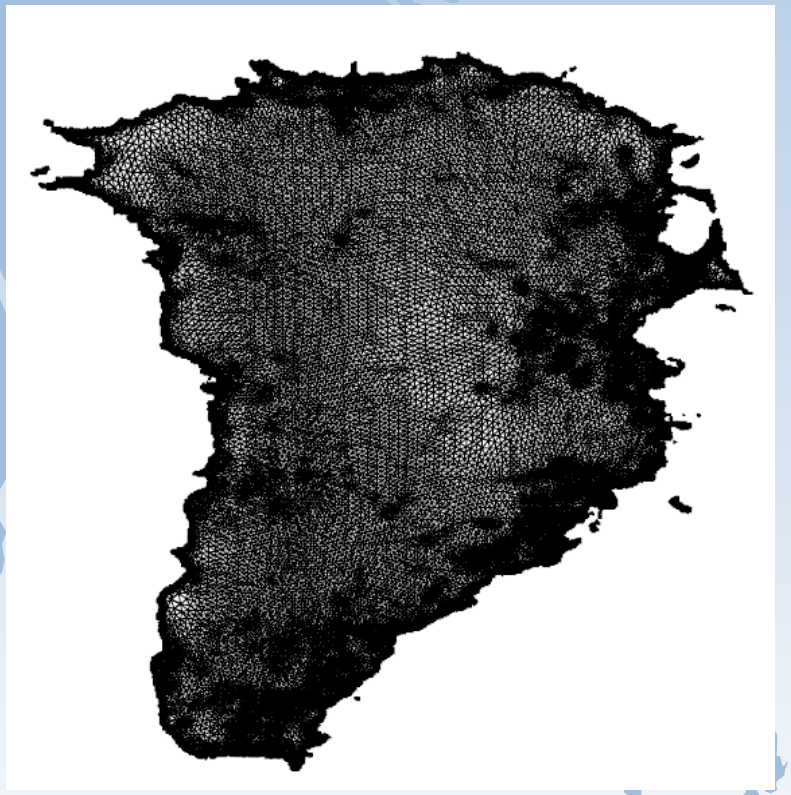
- Fully coupled climate system model with extensive interactive chemistry and biogeochemistry
  - Carbon and sulfur (and nitrogen) cycles within CCSM model
  - Needed to assess ability of oceans and land to sequester carbon
  - True emissions scenarios
  - Aerosol feedbacks
  - Atmosphere, ocean and land exchanging CO_2 and dimethyl sulfide fluxes
  - Atmosphere: 90-100 chemical compounds and over 200 interactions
  - Ocean: ecosystem and trace gas model with 26 species (plankton, nutrients, detritus…)
  - Land: many carbon pools and dynamic vegetation



Dimethyl sulfide flux (nanomoles/m^2/sec)
from Ocean to Atmosphere
December Average of Coupled Year 5

Model Integration and Evaluation

- New ice sheet and ocean models
- New atmospheric dynamics: finite volume (cubed sphere), discontinuous Galerkin, others (icosahedral)
- Frameworks for model evaluation
- Strong analysis component

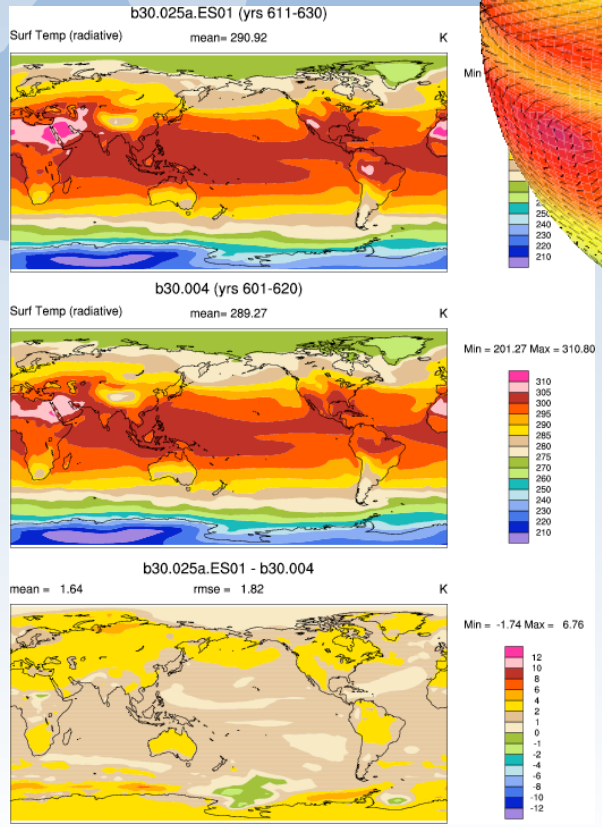


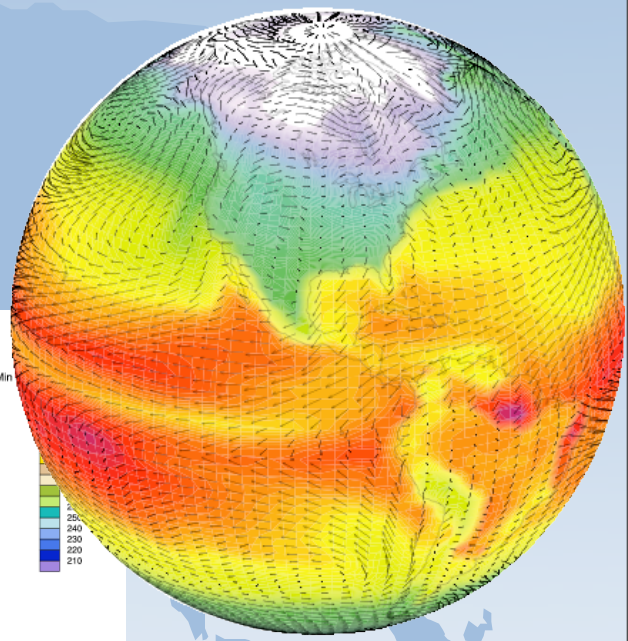
Laundry List of Viz/Analysis Needs

Disclaimer: product placement in no way implies an endorsement of a specific product

Routine Laundry

- Machine wash warm/ tumble dry low
  - Colormaps, contours
  - Vector plots
  - Line plots
  - Multi-variable
- Generic detergent
  - CDAT (LLNL PCMDI)
  - Ferret (NOAA PMEL)
  - NCL (NCAR)
  - IDL (RSI)
  - ParaView
- Viz needs very primitive (stones by the creek) – more on analysis side
- Lack imagination?





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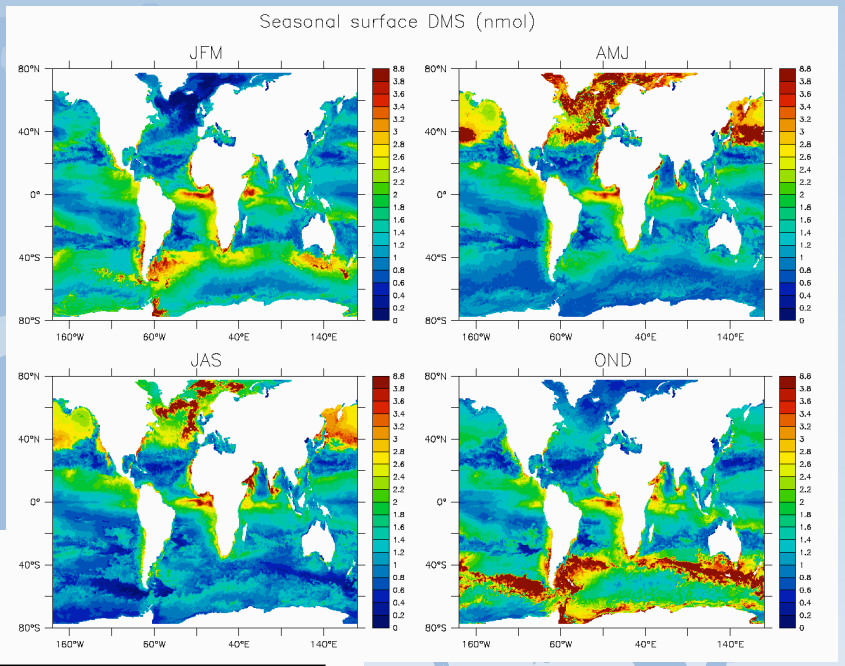
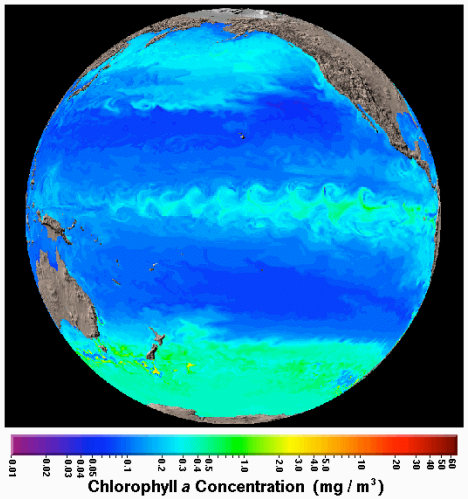
Earth System Model

- Bright colors
  - Similar basic cycle
  - Many tracers
  - Tracer interactions
  - Correlations
- New field – analysis will evolve rapidly





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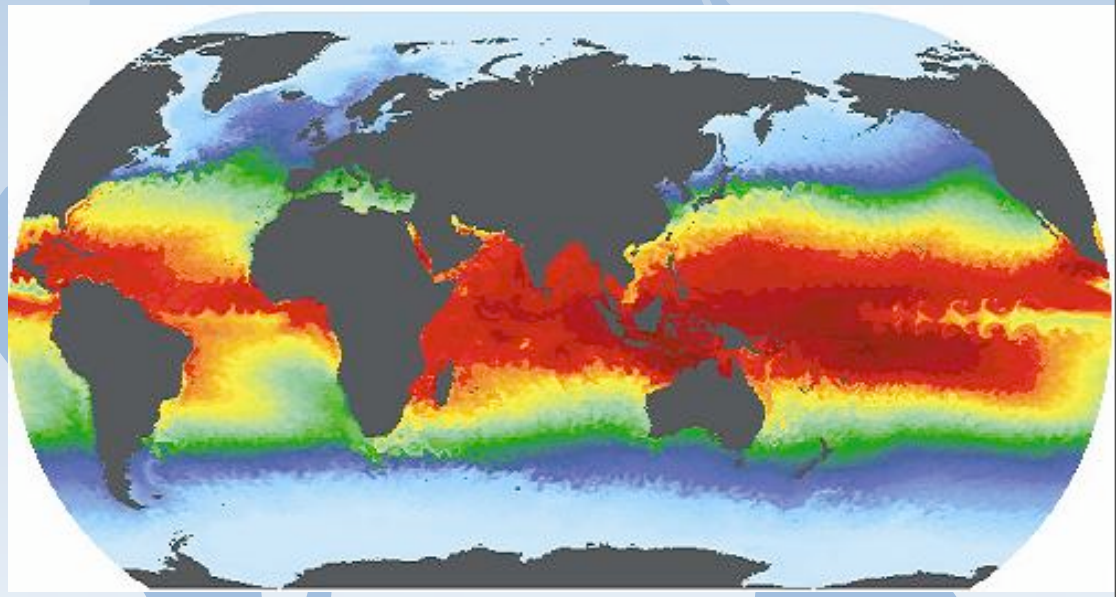
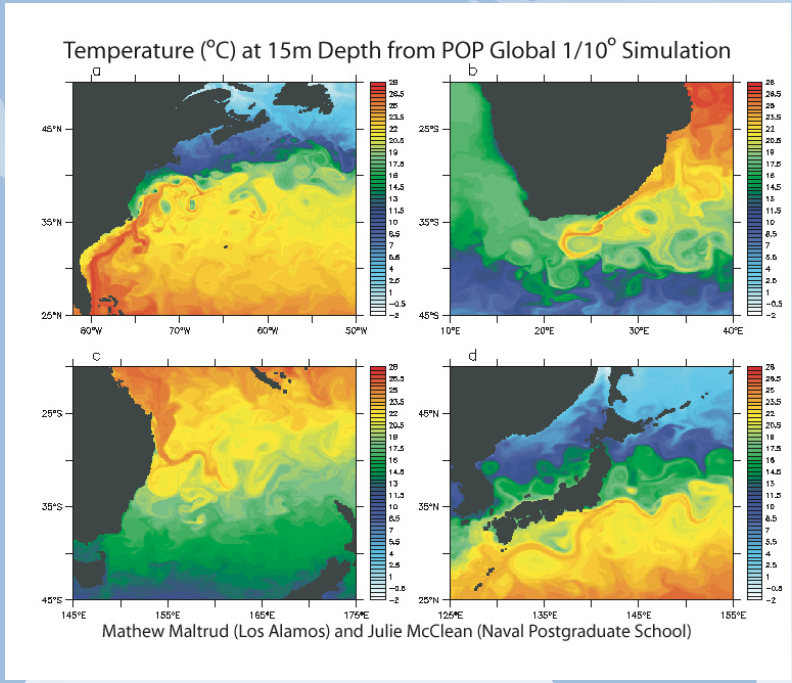
Heavy-duty cycle

- High-res simulations
- Each field 1.4GB
- Derived fields/ analysis require more memory
- Reqmt
  - Parallel analysis
  - Subsetting or out-of-core



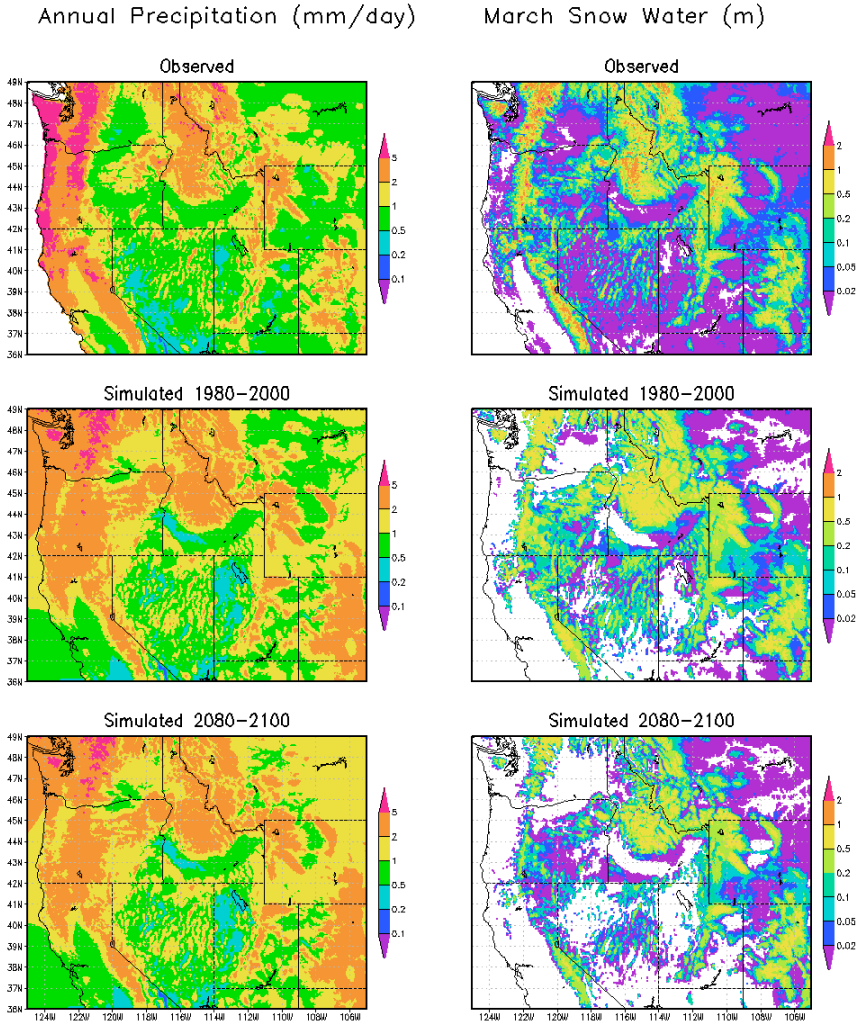
Regional Analysis/Prediction

- Regional analysis of global data
- Nesting/regional prediction
- Geographically-based subsetting
  - Grids not aligned



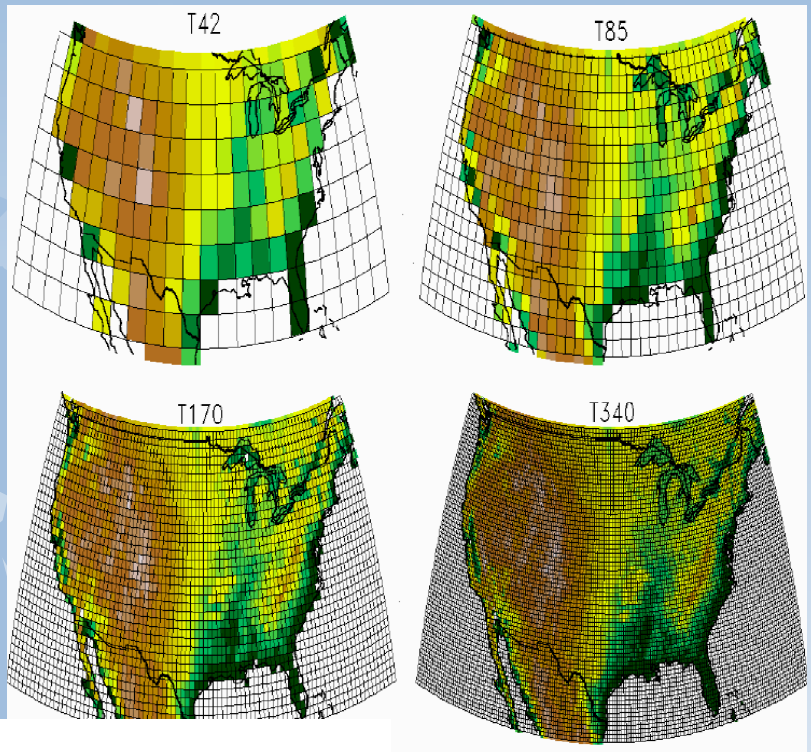
Comparative Viz/Analysis

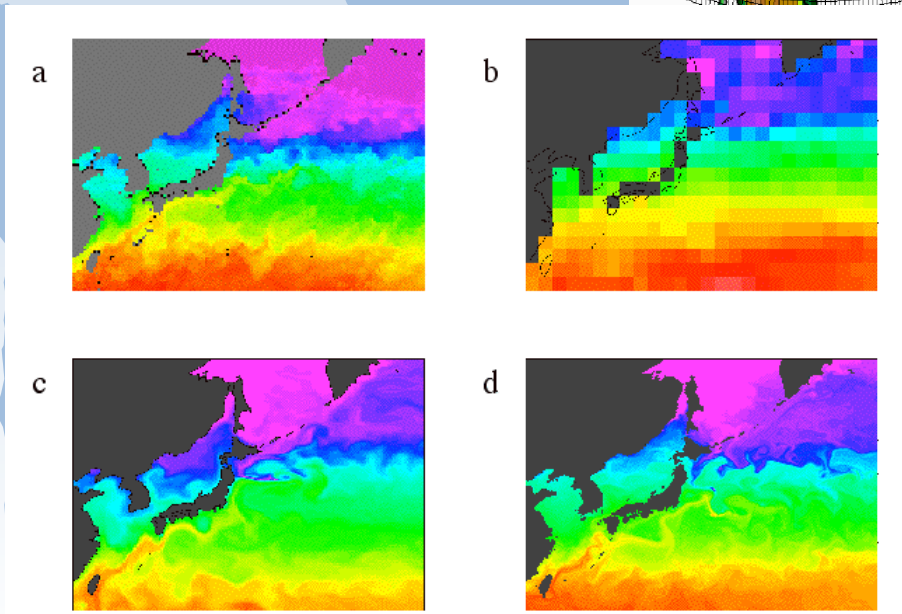
- The LG norm
- 2d horizontal slices
- Meridional/zonal sections
- New tools



Multi-resolution comparisons

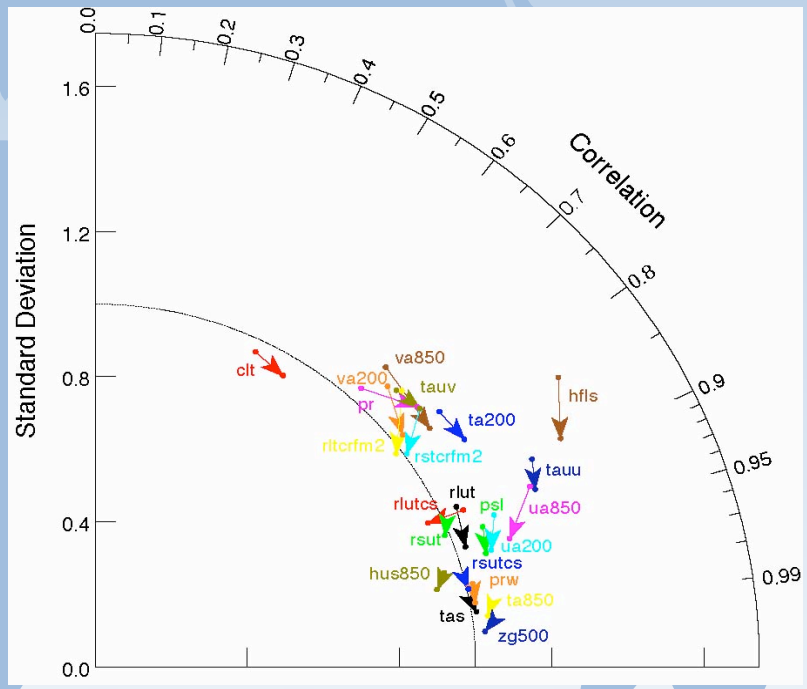
- Convergence
- Sub-grid vs. fully resolved





Stain Removal: Model Evaluation and Removing Pesky Biases

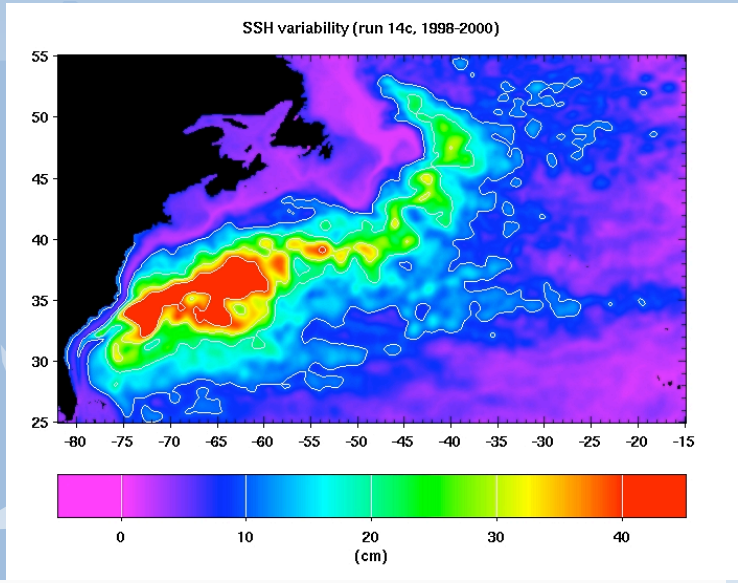
- How to determine "goodness" of model
  - Metrics
- Tradeoffs, priorities
- Compare with data, other models
- Needs
  - Define/incorporate standard metrics

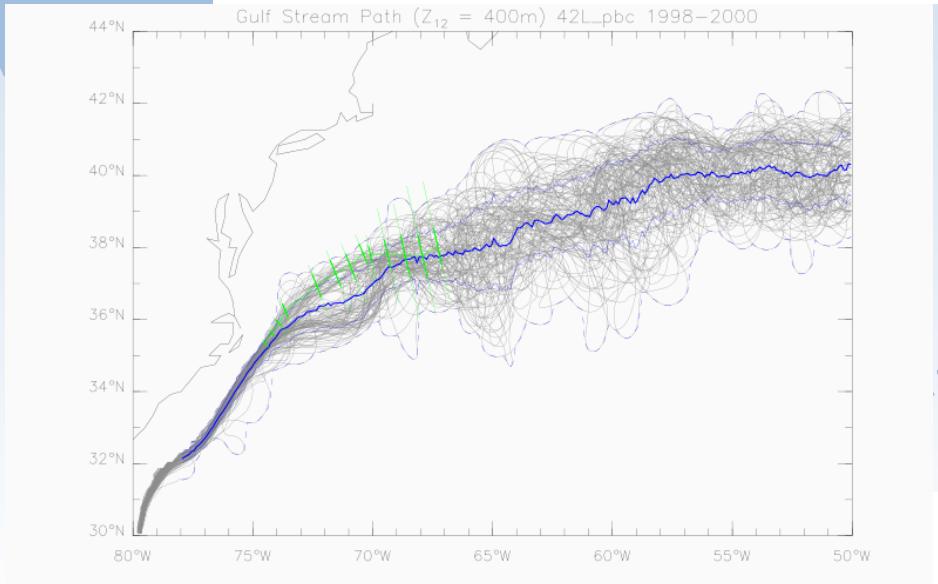


Taylor diagrams

Pattern Shifts

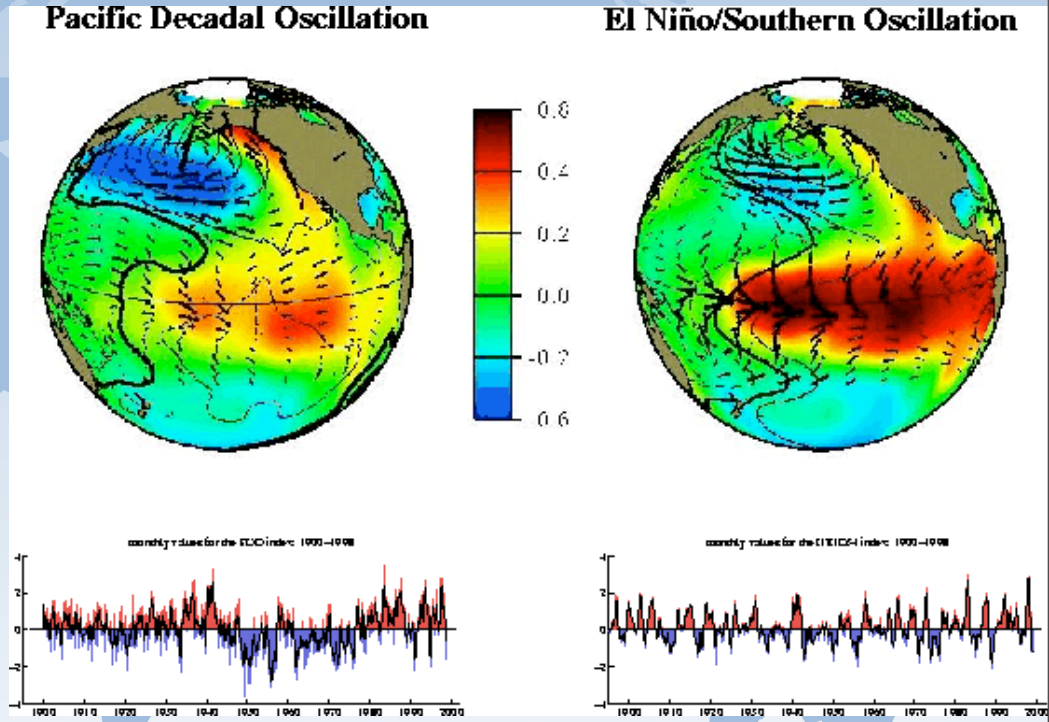
- Current locations
- Biases result in shifts or changes in location
- Some shifts are real
- Needs:
  - Means for determining locations
  - Comparison of shifted patterns





Time Series

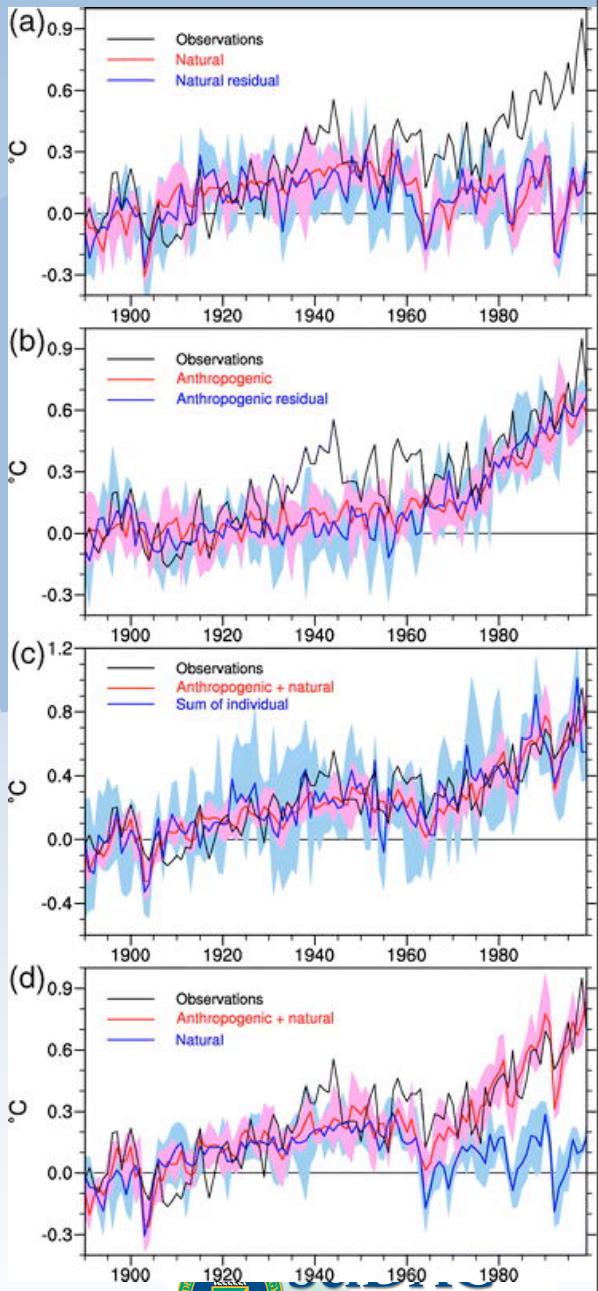
- Climatology
- Seasonal cycles
- Analysis of modes of variability
- Spectral analysis
- Empirical Orthogonal Functions (EOF)



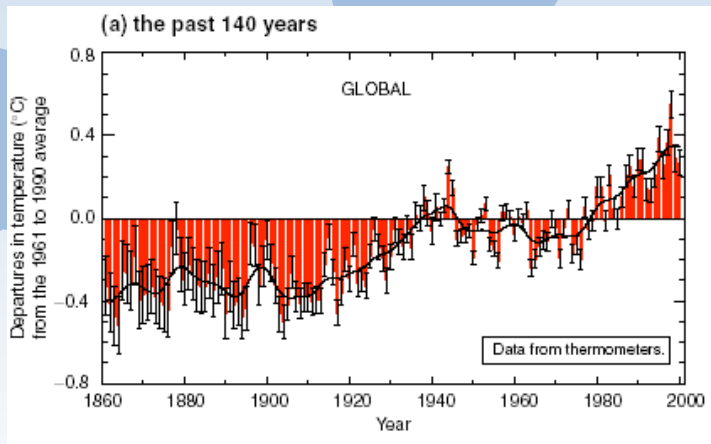
IPCC and Attribution

- Ensembles
  - Simulations
  - Models (IPCC)
- Statistical measures for estimating uncertainty
  - Input to policy makers

Meehl



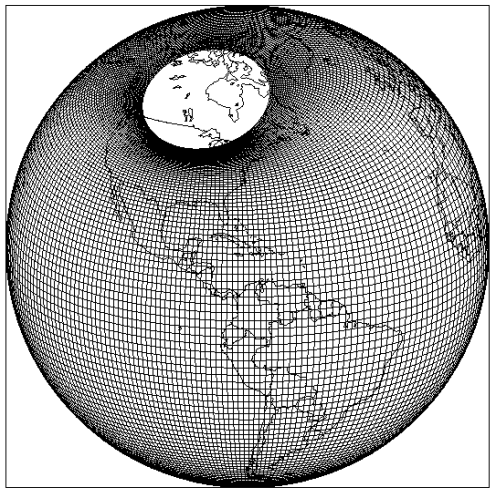
The Hockey Stick



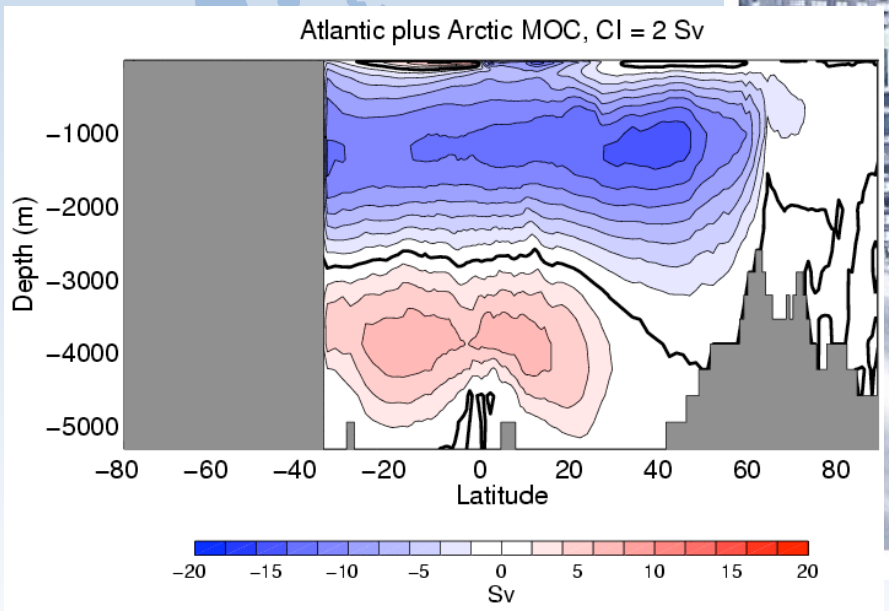
IPCC Third Assessment

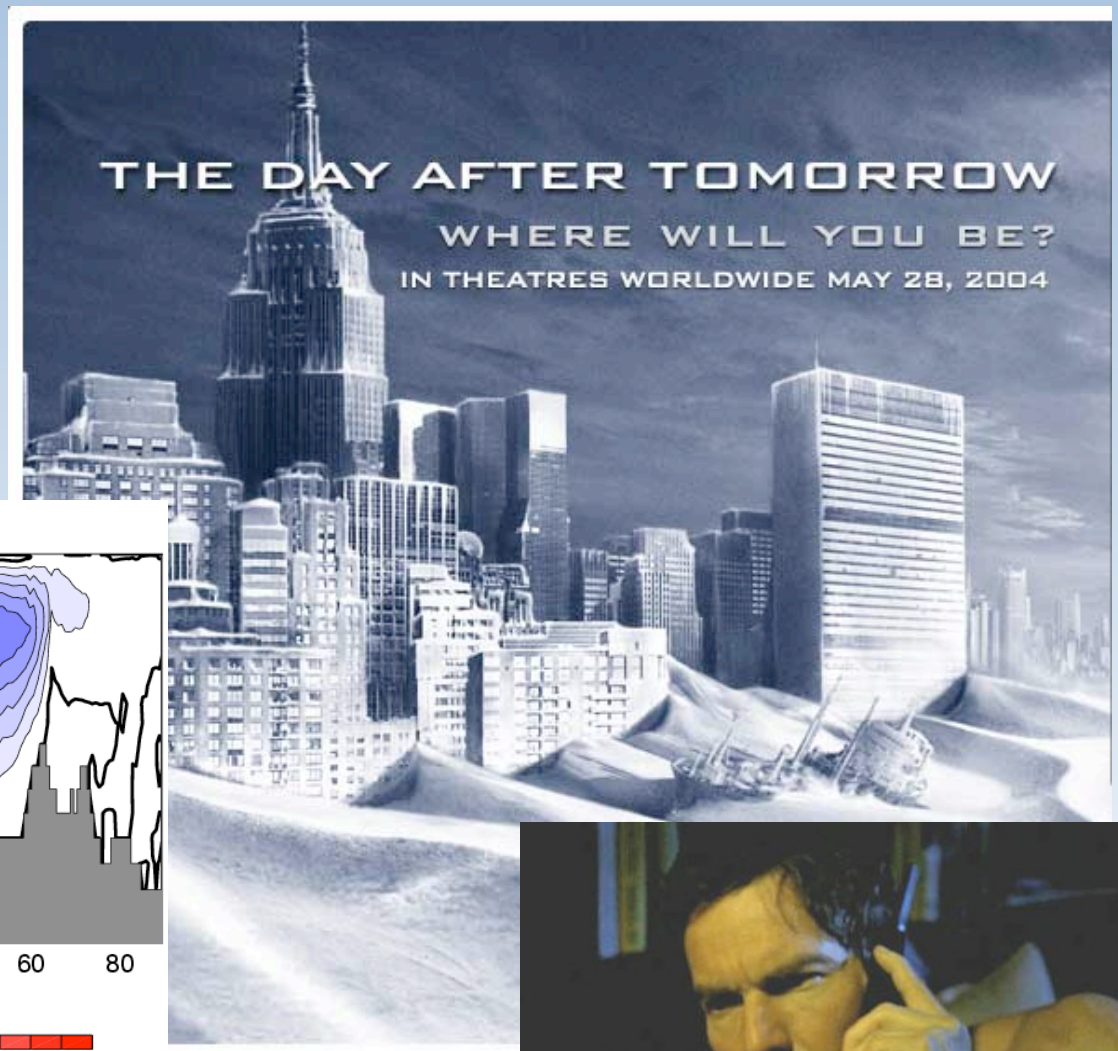
Horizontal Grids

- Needs
  - Regridding (SCRIP)
  - Some analyses must be performed on native grid (MOS, MHT) but presented in lat/lon space
  - Flexibility to incorporate routines written by subject matter experts



Thermohaline Circulation Collapse





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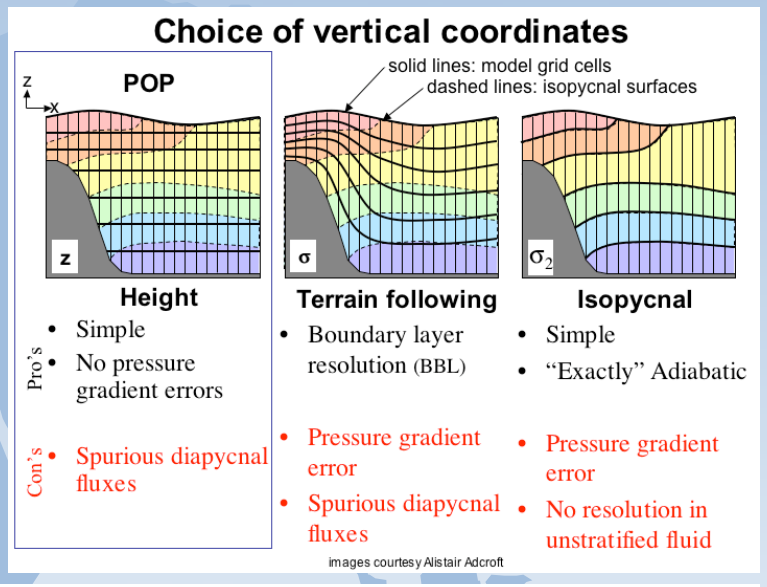
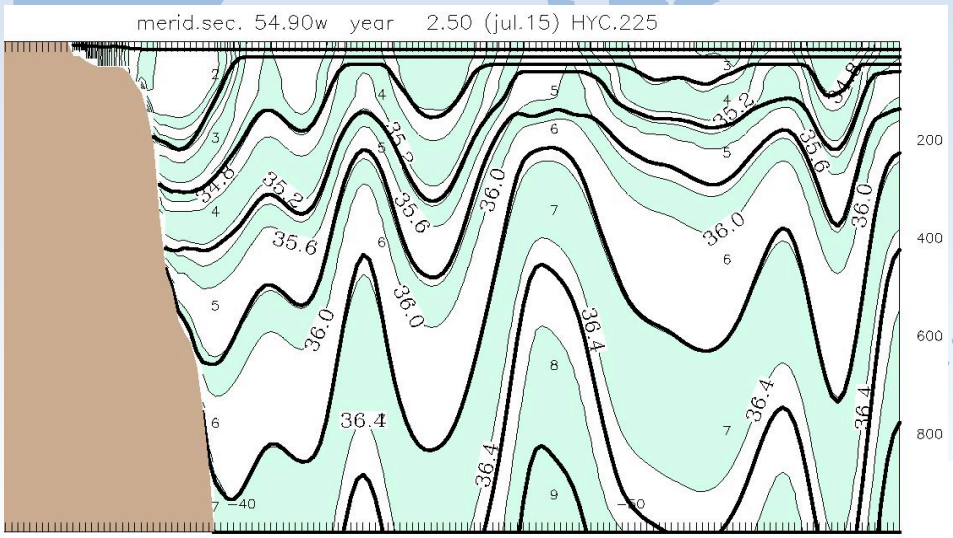
Vertical grids

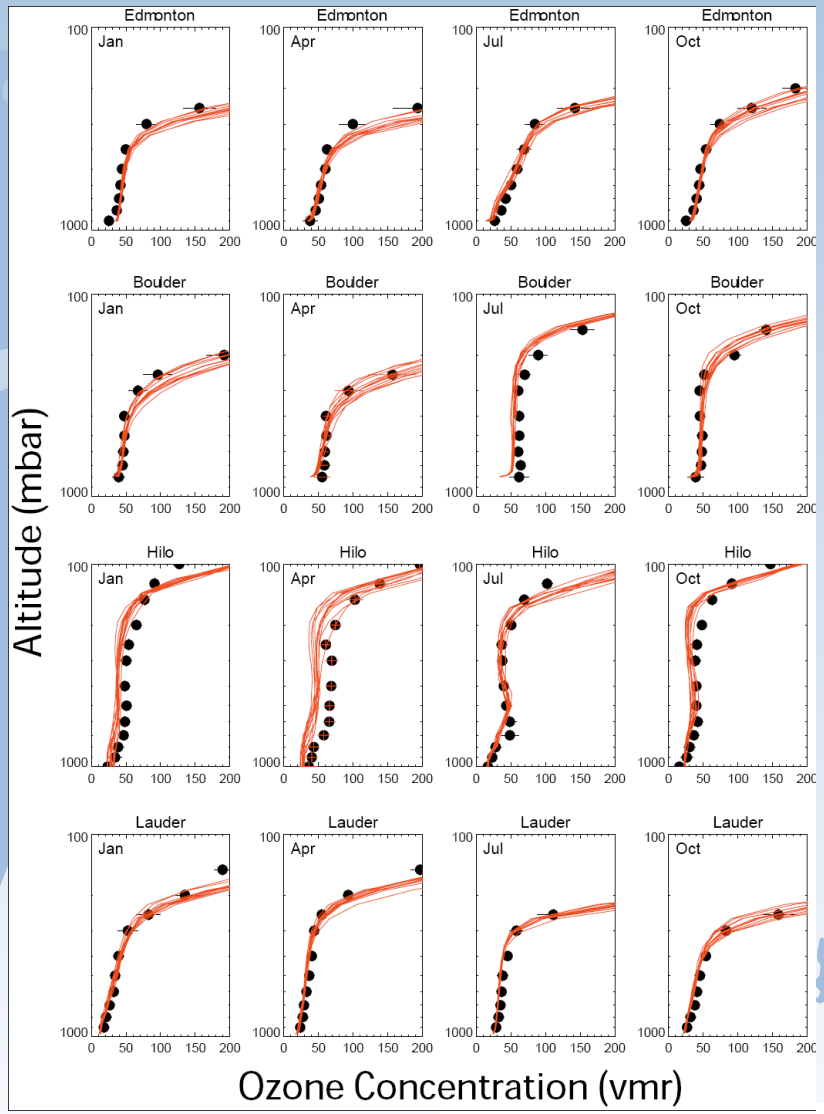
- Different choices
  - Geometrical
    - Height/depth
    - Stretched
    - Terrain following
  - Physical
    - Isentropic
    - Isopycnal
    - Pressure
  - Hybrid
  - Lagrangian
  - Interpolation non-trivial





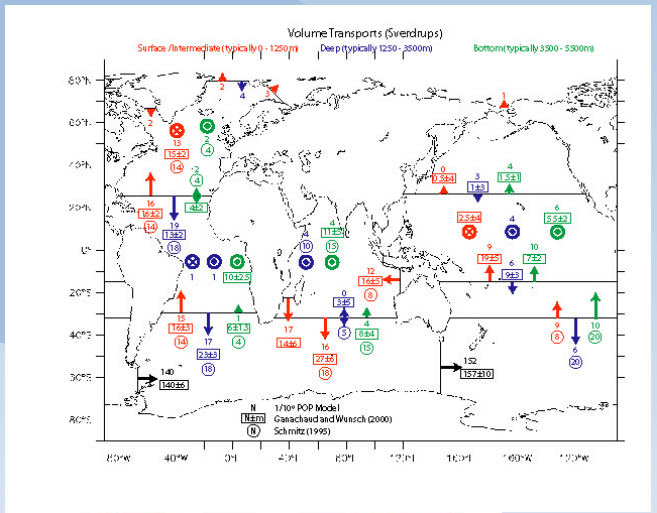
Point/regional observations

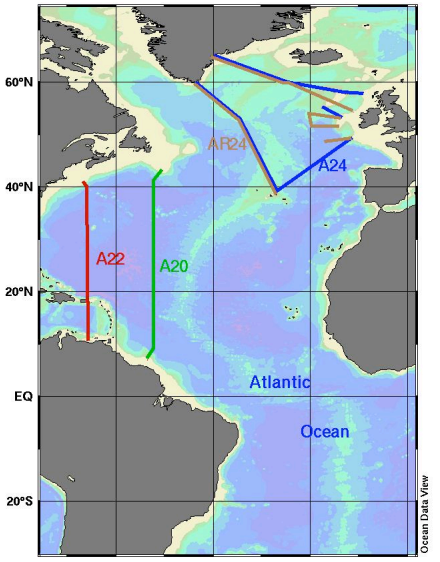
- Station data
  - Comparison location w/ gridded data
- Interpolation
  - Representative points
  - Pattern shifts/biases



Drying (drawing) on the line: Sections and Transports

- Transport across sections
- Hydrographic sections
- Analysis difficult
  - Grid not aligned with section
  - Pattern shifts/biases
- Reqmts:
  - Arbitrary slicing/dicing
  - User-supplied routines





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Powdered Detergent: Lagrangian Particles

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Dynamic Vegetation

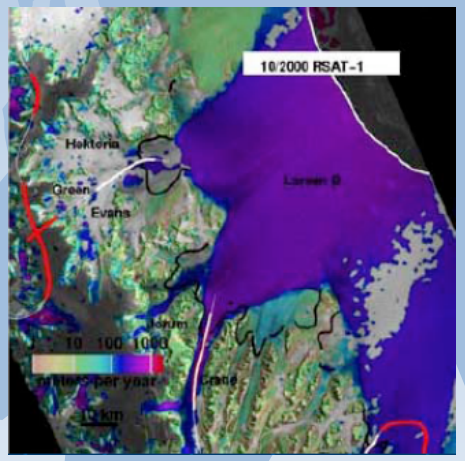
- New land surface models will allow ecosystems to change
- Ecosystems migrate
  - Location (eg N/S)
  - Altitude
- GIS integration?

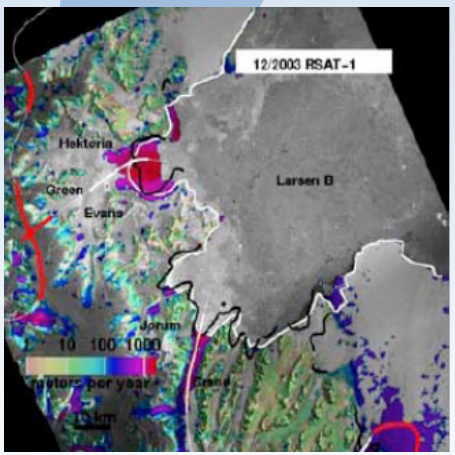
Los Alamos 90% Pinon mortality – Craig Allen

Disappearing Socks: Sea Level Rise/Ice Sheets

- Topography changes
- Continental boundaries change
- Topography generation
  - Civil engineering

Oct 2000





Dec 2003 Rignot et al. 2004

Stephen Leatherman

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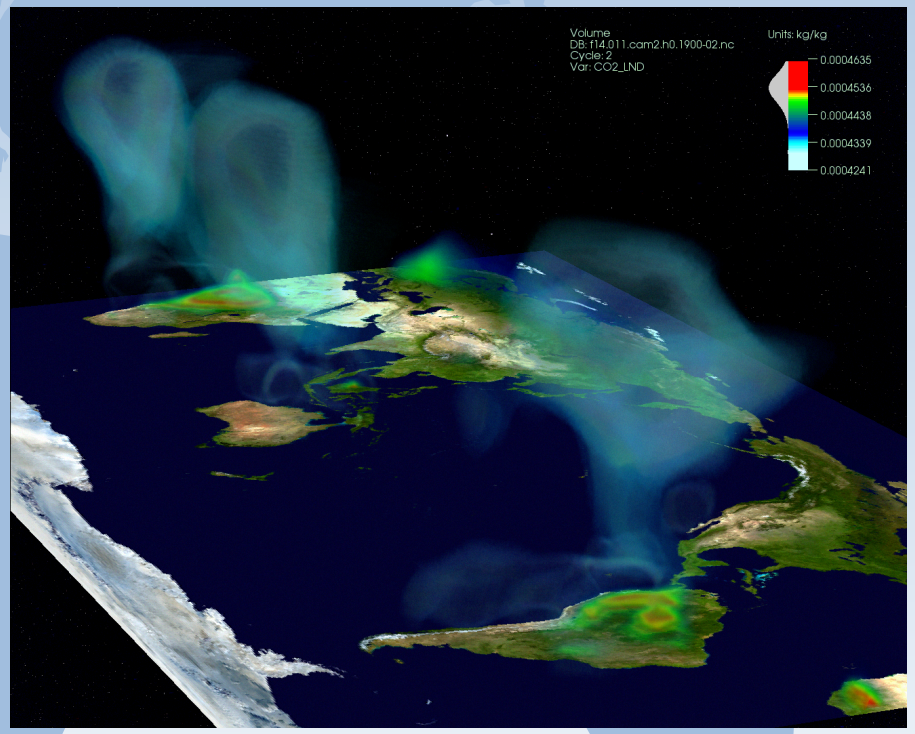
Delicate Fabrics/Dry Cleaning

- No Simulation Left Behind
  - Each large simulation effort should have associated marketing graphic



Courtesy Jamison Daniel

Laundry Baskets and Data Management

- Remote data
- Collections of data (PCMDI)
- Remote viz/analysis of large data sets
  - Track results before transferring data
- Earth System Grid (ESG)

Summary

- "Standard" viz tools
  - Incorporate/integrate existing packages
- Grid/meshing capabilities
  - Regridding, subsetting, esp. non-aligned grids
- Comparative analysis
  - Move beyond the LG norm
- Comparison with non-gridded data
  - Station data, floats/drifters, sections/transports
- Analysis methods for determining model validity
  - Pattern recognition/shifts, multi-variate measures, new statistical measures
- Data management
  - ESG, remote access to observ. data and intercomparison data
  - Large dataset sizes
- Customizable
  - Subject matter experts must devise some of the above
- 3D viz